STUDIES OF TILL FROM KELLY'S ISLAND, OHIO

Geology 570, Senior Thesis

by

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for

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ABSTRACT

Samples of till were taken during the uncovering of the glacial grooves on Kelly's Island, Ohio, in 1972. These samples were analysed by laboratory procedures to classify the till in terms of Ohio glacial stratigraphy, and to determine the mode of origin of the till, i.e. whether it is an ablation or lodgement till. It was found that the till is the Hiram Till of the Late Cary-Woodfordian substage, and is a lodgement till.

INTRODUCTION

During the summer of 1972, the remaining extension of the famous glacial grooves on Kelly's Island, Ohio was unearthed under the guidance and financial support of the Ohio Historical society. The material covering the grooves consisted of a thin layer of till which pinched out toward the southwest upper end of the remaining composite groove. This till was overlain by poorly sorted sand, which was in turn overlain by limestone and soil debris from nearby quarrying operations. During the excavation of these deposits, five grab samples of till, and two of the overlying sand were taken.

The classification and correlation of tills in Ohio has been established by both field observations and laboratory procedures. In the field, stratigraphic position, color, texture, hardness, mineralogy, and amount of weathering have been used to correlate till sheets. In the laboratory, mechanical analyses of grain size, clay mineralogy, mineralogy of both

heavy and light minerals, and carbonate content have been used. Those who have been instrumental in the development and use of this classification include G.W. White and his students at the University of Illinois, and R.P. Goldthwait and his students at Ohio State University.

The application of the terms "ablation" or "lodgement" to a till implies the condition of the ice at the time of deposition of the till. An ablation till implies thin, slow moving or stagnant ice which was melting downward, depositing its surficial and englacial load of sediment. A lodgement till implies an ice sheet which was actively moving at its base at the time of deposition of the till. As the ice moves, the till is emplaced by basal melting, or the plastering of the basal load of sediment to the subglacial floor (Goldthwait, 1971).

At least one study was conducted (Drake, 1968) in which 82 different characteristics of tills were quantified by computer. About 30 of these proved useful in terms of supporting either an ablation or lodgement genesis for a given till. This study attempted to apply some of the same characteristics to show that Drake's hypotheses can be useful in other areas.

PROCEDURES USED FOR CORRELATION

In this study, the procedures used to correlate the till with the stratigraphy defined by White (1960) included grain size, clay mineral, and carbonate content analyses, and color determinations. White's original stratigraphy is shown in Table 1. Since this stratigraphy was introduced, both the time "substage" names and the correlations have been changed

TABLE 1

GLACIAL STRATIGRAPHY IN OHIO

EPOCH	STAGE	SUBSTAGE	UNIT	DESCRIPTION OF MATERIAL
Pleistocene	Wisconsin	Cary	Ashtabula Till	Silty to Silty-Clay Till
			Hiram Till	Silty Clay to Clay Till
			Lavery Till	Silty Till
			Windham Sand	Medium to Fine Sand Outwash Equivalent of the Lavery Till
			Kent Till	Silty, Sandy Till
		Tazewell	Mogadore Till	Sandy Till
		Farmdale?	Unnamed Loess	Silt

Table 1 after White (1960, Grand R. Lobe)

and been modified by other users. The basic till units are still accepted.

MECHANICAL GRAIN SIZE ANALYSES

The grain size analyses were performed to determine the percentages of sand, silt, and clay by weight of the total weight of sand, silt, and clay in the sample. The samples were split to a convenient size, about 100 grams, and oven dried for accurate weighing. After weighing, the samples were disaggregated by placing them in bottles, adding water, and shaking them overnight on a reciprocating shaker.

The disaggregated samples were wet sieved through a 0.063 mm. sieve to remove most of the silt and clay from the sand fraction. The size range for sand sized particles was taken to be 2 mm. to 0.063 mm. The sand fraction was redried, then dry sieved through a standard set of Tyler sieves by shaking them on a Tyler sieve shaker for ten minutes. The material passing through the 0.063 mm. sieve was added to the material separated during the earlier wet sieving, and placed in a 1000 ml. cylinder for hydrometer analysis. The weight of the sand fraction was recorded and used to determine the per cent of sand, by weight, of sand, silt, and clay in the sample.

The hydrometer method (ASTM, 1964) was used to find the percentages of silt and clay in the sample. The dispersant used was 0.5 N sodium carbonate. The clay-silt break was taken to be 0.002 mm. (2 microns). In this study, the per cent of clay was determined, and the per cent of silt taken as 100% minus the percentages of sand and clay.

CLAY MINERAL ANALYSES

The samples used in the hydrometer analysis were placed in bottles for separation of silt and clay by settling (Jackson, 1956). The material was stirred using a magnetic stirrer, then allowed to stand for the time required for particles of 0.002 mm. size to settle 10 cm. After the required time interval, depending on the room temperature, the clays were siphoned off at a depth of 10 cm. This was repeated six times to insure that all of the clay was separated from the silt.

The clays were flocculated with sodium chloride to reduce the volume for easier handling, then treated with 0.5 N magnesium chloride and methanol for redispersal (L.P. Wilding, personal communication, 1971). The dispersed clays were plated by vacuum onto ceramic tiles to produce a clay film of preferred orientation for analysis by X-ray diffraction.

Three tiles were plated for each sample, one being air dried at room temperature, one being placed in an ethylene glycol atmosphere, and one being heated for 2 hours at 400° C in a muffle furnace. The air dried sample was X-rayed, then heated for 2 hours at 550° C in the furnace, and re-X-rayed. These various treatments were done so that each of the minerals present would show its optimum peak on the X-ray diffraction strip chart.

CARBONATE ANALYSES

The original samples were resplit, and approximately 30 grams of the total sample was oven dried, then ground to pass a 200 mesh sieve. A chittick apparatus (Dreimanis, 1962) was used to determine the amount of CO_2 gas liberated on the addition of 20 ml. of 6 N HCl to 1.7 grams of the ground sample.

Dolomite reacts more slowly with the acid than calcite, which makes their distinction possible. The volume of gas liberated during the first 30 seconds after addition of the acid was used to calculate the percentage of calcite in the sample. Four percent of this volume was assumed to be contributed by dolomite. The volume liberated after 30 seconds was used to calculate the percentage of dolomite.

COLOR

The color of fresh surfaces on different pieces of dry till samples were compared with the colors on a standard Munsell soil color chart. Some of the samples were soaked in water and compared with the chart to determine the wet color of the samples.

RESULTS OF THESE ANALYSES

MECHANICAL ANALYSES

The data from the mechanical grain size analyses are shown in Table 2. These data agree with those of Shepps (1953), Campbell (1955), and Dreimanis (1953) for the Hiram Till in Northeastern Ohio, North Central Ohio, and Southern Ontario, respectively (although Dreimanis named the correlative till in Southern Ontario the Port Stanley Till). This agreement is shown in Figures 1 and 2. The data had to be recalculated for comparison with Dreimanis' work because he used the percentages of sand and gravel, silt, and clay in his diagrams, rather than sand, silt, and clay as used here and by the others.

The analyses of the sand overlying the till show a poorly sorted sand. This presumably represents a temporary reworking of the

TABLE 2

MECHANICAL GRAIN SIZE ANALYSIS DATA

Sample Number	Grain Size % Sand	Silt	Clay	Sample Material
KI 1	6	57	37	Till
KI 2 ×	38	47	15 ×	Sand
KI 3	13	49	38	Till
KI 4	12	51	37	Till
KI 5	8	57	35	Till
KI 6	6	54	40	Till
KI 7 ×	37	37	26 ×	Sand

Triangular Co-ordinate

12-082

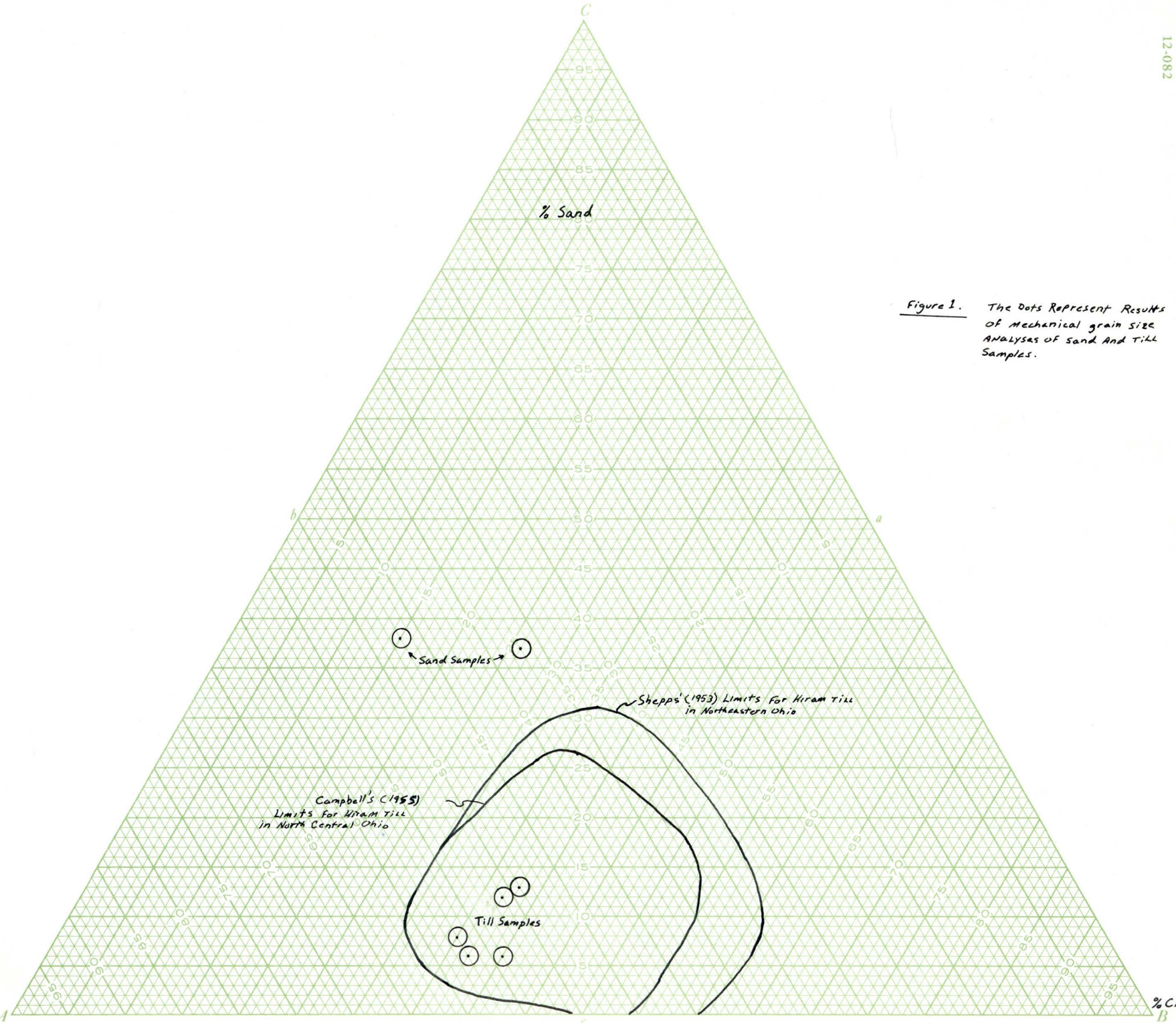

Figure 1. The Dots Represent Results of Mechanical grain size Analyses of sand And Till Samples.

Triangular Co-ordinate

12-082

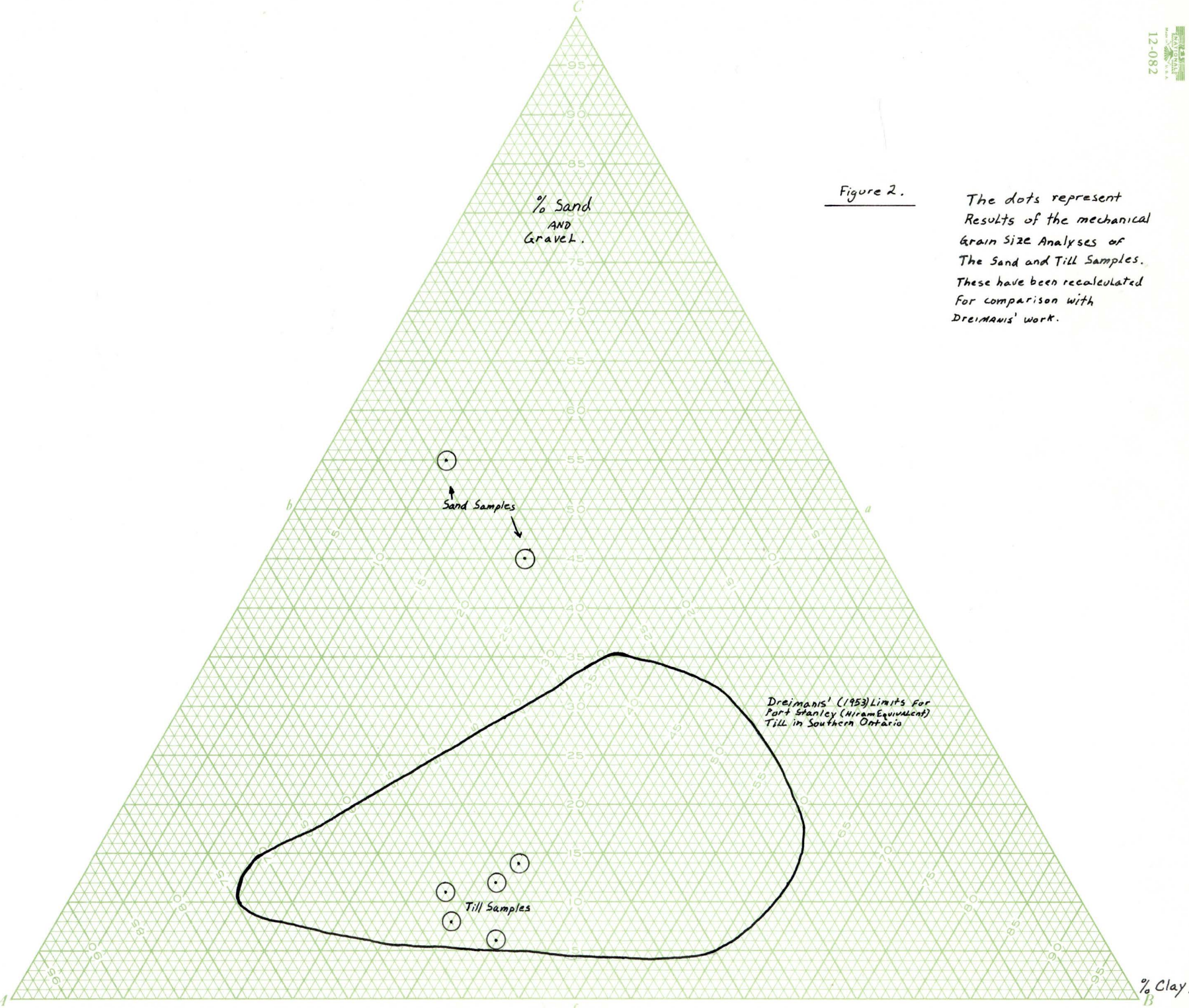

Figure 2.

The dots represent Results of the mechanical Grain Size Analyses of The Sand and Till Samples. These have been recalculated for comparison with Dreimanis' work.

till during the high lake levels of Lake Erie, with the clay particles being winnowed away. Waters stood at this level, about 620 feet, as they fell bit by bit in the Lake Whittlesey and Lake Warren stages about 12,000 years ago.

CARBONATE ANALYSES

The results of the carbonate analyses are presented in Table 3. It is held (Goldthwait, 1965) that the Hiram Till is the parent material for the Morley soils in Northwestern Ohio, because of their high clay content and geographical distribution. Results of carbonate analyses of the IIC4 horizons of these same soils (Wilding et al, 1971) are: calcite, 14-16%; dolomite, 7-12%; total carbonate, 21-27%; calcite/dolomite ratio, 1.2-2.2. There is a fairly close agreement between these values and those shown in Table 3, indicating that the till found on Kelly's island is the Hiram Till.

CLAY MINERAL ANALYSES

Data from the clay mineral analyses are shown in Table 4. A comparison with analyses by Wilding et al (1971) of the IIC4 horizon of Morley soils of Northwestern Ohio show an agreement in minerals, and approximate agreement in percentages of each mineral present. Their results are: illite, 80%; vermiculite, 10%; quartz, kaolinite, and chlorite, each, less than 5%; interstratified 10-14 A clay minerals, trace; expandables (montmorillonite), not detectable. This agreement also offers evidence that the till is the Hiram Till.

COLOR

The color of the dry till was 7.5 YR, 7/2 on the Munsell color chart, or a pinkish grey. The color of a wet sample was

TABLE 3

CARBONATE ANALYSIS DATA

Sample Number	Carbonate % Calcite	Dolo.	Total	Calc./Dolo. Ratio
KI 1	16.1	8.6	24.4	1.8
KI 2	21.2	15.9	38.4 X	1.3
KI 3	12.3	8.6	21.6	1.4
KI 4	12.6	7.8	21.1	1.6
KI 5	15.8	8.9	25.4	1.8
KI 6	13.0	8.2	21.9	1.6
KI 7	11.8	13.2	26.0 X	0.9

TABLE 4

CLAY MINERAL ANALYSIS DATA

Sample Number	Clay Minerals* %						
	I	V	E	Q	K	C	Int.
KI 1	68	29	ND	2	1	ND	ND
KI 2	78	13	ND	6	ND	3	ND
KI 3	68	21	T	7	1	3	ND
KI 4	72	24	T	1	ND	3	ND
KI 5	63	26	ND	11	ND	ND	ND
KI 6	65	32	ND	3	ND	ND	ND
KI 7	79	14	ND	7	ND	ND	ND

*
I= Illite
V= Vermiculite
E= Minerals with variable expansion beyond 14A upon glycolation (mostly montmorillonite)
Q= Quartz
K= Kaolinite
C= Chlorite
Int= Interstratified 10-14A clay minerals
T= Trace
ND= Not dectable

7.5 YR, 4/4, or a dark brown to brown. G.W. White (1965) described the Hiram Till as a dark brown clayey till. Assuming that the color given by Dr. White is the wet color, this offers further evidence that the till is the Hiram Till.

CONCLUSIONS

It can be concluded therefore, that the till found on the grooved surface at Kelly's Island is the Hiram Till. Strong evidence lies in the results of the mechanical and carbonate analyses. Slightly less support is offered by clay mineralogy and color determinations.

CLASSIFICATION OF THE TILL BY GENESIS

INTRODUCTION

A genetic classification of till includes two main groups, basal or lodgement till, and ablation till (Goldthwait, 1971). Lodgement till is that which is deposited at or from the base of a flowing glacier by basal melting, or by interference with the bottom. Due to the pressures generated under the ice sheet, the till is compacted, and the pebbles in the till are usually crushed and abraded, and strongly oriented with their long axes parallel. Ablation till consists of superglacial or englacial debris brought to the surface in inclined shear zones, and deposited as the glacier melts away. This material is not compacted, and the pebbles present aren't oriented or abraded as often or as strongly as in lodgement till.

L.D. Drake (1968) studied 82 different characteristics of tills in New Hampshire. He found that a few of these lend ex-

clusive support to either an ablation or a lodgement origin for a till. The characteristics which Drake found to be distinctive evidence for the mode of origin of a till which were also used in this study include mechanical analysis data, pebble shape data, pebble roundness data, and internal structure or compactness of the till.

MECHANICAL ANALYSIS DATA

As seen in Table 2, the till from Kelly's Island contains high percentages of silt and clay. This seems to indicate a basal origin for the till. An ablation till would have a higher percentage of coarse material due to the washing away of the fines by meltwaters. However, so little such sandy till exists in Ohio that this criterion may be uncertain with the sedimentary rocks involved.

PEBBLE SHAPE DATA

The method used by Zingg (1935) of determining pebble shapes from axial measurements was used in this study on 200 pebbles ranging in size from 10 to 200 mm. Of these pebbles, 26.5% were spheres, 54.5% were discs, 11.5% were rods, and 7.5% were blades. The flattened shapes are clearly the most abundant. This indicates abrasion in an environment where flattened shapes have the highest stability, namely the basal shear planes at the bottom of an ice sheet.

Coinciding with the abundance of flattened shapes, is a high percentage of striated and faceted pebbles (65 and 16 per cent respectively). This indicates intense grinding such as occurs at the base of a glacier. Both the shape data, and the large numbers of striations point to a lodgement origin for

this till.

PEBBLE ROUNDNESS DATA

Drake maintained quite firmly that for a lodgement till, the average pebble roundness is 0.5 on the Krumbein (1941, Plate 1) scale. Perhaps on the crystalline rocks of New Hampshire it is. The average roundness of the pebbles used in the pebble shape analysis was 0.34. Considering that the writer may have judged the roundnesses wrong, the experiment described below was conducted.

PEBBLE ROUNDNESS EXPERIMENT

In this experiment, ten pebbles were selected at random from the 200 pebbles used above. Two geology professors, two geology undergraduate, and three geology graduate students individually determined the roundnesses of the same ten pebbles using the Krumbein scale. The results of the experiment showed a range of two roundness units (0.2) for nearly every pebble. Two of the subjects gave values consistently higher than or equal to the average value for each pebble, two gave values consistently lower than or equal to the average, two gave values consistently on the average, and one gave values varying higher, lower, and equal to the average.

With this much variability between individuals, it follows that this method may not be such a useful tool for correlation. It may be possible to improve the reliability of roundness values by greater standardization of the technique, such as the use of light tables to insure that only the silhouette of the pebble is seen. Because of the inconsistencies of the method, shown by the experiment, it is felt that the pebble roundness data could

not be used as good evidence for either an ablation or lodgement origin for this till. Drake's work may still be valid, because he considered only igneous and metamorphic lithologies which were isotropic and homogeneous. Such rocks would show a more uniform rounding, thus making the roundnesses easier to judge, and more consistent.

INTERNAL STRUCTURE OF THE TILL

Drake found that the ablation tills consist of layers and lenses with varying grain size compositions. The lodgement tills on the other hand, are massive and homogeneous. The massive structure and also the generally higher clay content of lodgement tills make them much harder to excavate than ablation tills. The till found lying above the grooves was indeed massive and very difficult to remove. Jackhammers were necessary for the excavation. The compaction of the till then, further supports its deposition in a basal environment.

CONCLUSIONS

The mechanical analyses, pebble shapes, and internal structure of the till all indicate a lodgement origin of the till. It was found that pebble roundness determinations may vary widely between investigators, so as used here, this is an unreliable means of correlation of data compiled by different people.

HISTORY OF THE LOCATION

The erosional and depositional features on Kelly's Island show a history made complex by periodic advances and retreats of the glaciers. C^{14} ages (those used here are from Dreimanis and

Goldthwait, 1973) show that the grooves were cut and scoured about 20,000 ± 2,000 years BP during the advance of the ice in Tazewell-Woodfordian time. The ice retreated and a warm period, the Lake Erie Interstade, followed, which lasted less than 1,000 years. As the ice readvanced, the till found in the grooves was deposited at about 15,000 ± 500 years BP during the Late Cary-Woodfordian substage. The ice retreated again, and at 12,000 ± 500 years BP, the area was free of ice, but still under water.

The lakes in the Erie Basin at that time, Lakes Whittlessey and Warren, reached levels greater than 700 feet (Campbell, 1955). As the ice retreated farther, the lake levels gradually fell, reworking the top of the till to sand and gravel until the island was exposed as it is today. A period of weathering of the upper exposed parts of the grooves followed which lasted until approximately 100 years age when slabs and soil from quarrying operations were dumped on top of the material covering the grooves.

SUMMARY

The till which was deposited above the scoured surface of the glacial grooves on Kelly's Island is the Hiram Till, and is a lodgement till. Mechanical analysis, carbonate analysis, and clay mineral analysis data were the most useful tools for correlating the till with established Ohio glacial stratigraphy. Mechanical analysis, and pebble shape data, and structure of the till were the most useful criteria for classifying the till on the basis of its genesis. It was found that pebble roundness data may not be a good correlative tool due to variations in judgement between scientists.

ACKNOWLEDGEMENTS

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REFERENCES CITED

American Society for Testing and Materials, 1964, 4th Edition.

Campbell, L.J., 1955, Glacial geology of Erie County, Ohio: Ph.D. dissertation, Ohio State University.

Drake, L.D., 1968, Till studies in New Hampshire: Ph.D. dissertation, Ohio State University.

Dreimanis, A., 1953, Lower and upper tills of the north shore, Lake Erie: Jour. Sed. Pet., v. 23, p. 238.

Dreimanis, A., 1962, Quantitative gasometric determination of calcite and dolomite using chittick apparatus: Jour. Sed. Pet., v. 32, p. 520.

Dreimanis, A., and Goldthwait, R.P., 1973, Wisconsin glaciation in the Huron, Erie, and Ontario Lobes: in, The Wisconsinon, Ed. by Black, Goldthwait, and Wilman: G.S.A. Bull. 136.

Goldthwait, R.P., 1965, Pleistocene deposits of the Erie Lobe: in, The Quaternary of the U.S., Ed. by Wright and Frey, p. 85.

Goldthwait, R.P., 1971, Introduction to till, today: in, Till/ a Symposium, Ed. by Goldthwait, p. 3.

Jackson, M.L., 1956, Soil Chemical Analyses-Advanced Course.

Krumbein, W.C., 1941, Measurement and geological significance of shape and roundness of sedimentary particles: Jour. Sed. Pet., p. 64.

Shepps, V.C., 1953, Correlation of Wisconsin glacial deposits in Northeastern Ohio: Jour. Sed. Pet., v. 23, p. 34.

White, G.W., 1960, Classification of Wisconsin glacial deposits in Northeastern Ohio: U.S.G.S. Bull. 1121-A, 12 p.

White, G.W., 1965, Northeast Ohio: in, INQUA, VIIth Congress, Guide Book for Field Conference G, Great Lakes-Ohio River Valley.

Wilding, L.P., Drees, L.R., Smeck, N.F., and Hall, G.F., 1971, Mineral and elemental composition of Wisconsin age till deposits in west central Ohio: in, Till/a Symposium, Ed. by Goldthwait, p. 290.

Zingg, T., 1935, Beitrag zur Schotteranalyse: Schweiz Min. u. Pet. Mut, v.5, p. 38.